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PARAMETRICS INC.

221 CRESCENT STREET, WALTHAM, MASSACHUSETTS 02154

DEVELOPMENT OF A
CHEMILUMINESCENT
OZONE DROP-SONDE

SUPPLEMENT TO
FINAL REPORT

Contract No. NAS 5-3638

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Prepared by

Lester Seiden
Parametrics, Inc.
221 Crescent Street
Waltham, Massachusetts 02154

for

Goddard Space Flight Center
Greenbelt, Maryland

I. INTRODUCTION

The chemiluminescent ozone drop-sonde was designed and constructed by Parametrics, Inc. under the sponsorship of NASA-GSFC. The details of its operation are described in the Final Report for Contract NAS 5-3638, entitled "Development of a Chemiluminescent Ozone Drop-Sonde," dated 15 July 1966.

On December 15, 1966 the first of the two ozone sondes, constructed under the above contract, was flown on a Nike-Cajun at WSMR. This document constitutes a report on this flight, and thus may be considered as a supplement to the above Final Report.

Due to a failure in the parachute deployment mechanism, no reliable ozone data was obtained from this flight. This report, therefore, will deal primarily with the pre-launch activities associated with readying the unit for flight.

II. THE CHEMILUMINESCENT OZONE-SONDE

A. Operation of the Sonde

The sonde is designed to be ejected from a sounding rocket at an altitude of approximately 65 km, and to descend by parachute, telemetering ozone concentration data as it descends. Continuous sampling is accomplished by "self-pumping," i. e. by influx of ambient air into an internal "ballast chamber" as the external pressure slowly increases. This chamber is allowed to evacuate spontaneously during the ascent portion of the flight. As the air is drawn into the sonde, it flows past a specially treated chemiluminescent surface. If ozone is present in the sampled air, the surface emits light, the light intensity being proportional to the mass of ozone per unit time being drawn into the sonde. This light is chopped, monitored by a photomultiplier tube, and the photomultiplier signal is amplified and telemetered.

In order to relate the ozone signal to the ambient concentration it is necessary to know the mass flow rate of air entering the ballast chamber. For this purpose the pressure and temperature of this chamber are monitored, and the flow rate calculated from their rates of change.

As a check on the overall system stability a small, stabilized incandescent lamp illuminates the sensing chamber periodically, yielding a "reference" signal.

There are five channels of output information:

1) Ozone (High sensitivity; x 20)
2) Ozone (Low sensitivity; x 1)
3) Ballast Chamber Pressure (0-5 torr)
4) Ballast Chamber Pressure (0-100 torr)
5) Ballast Chamber Temperature

B. Calibration of the Sonde

The sensitivity of the chemiluminescent material varies slowly while in storage; therefore, the sonde must be calibrated prior to flight. To accomplish this, a calibrator-simulator was constructed in which the expected pressure vs. time profile for the first ten minutes of the sonde's descent can be simulated with air of known ozone content. The sonde, when attached to the simulator will thus sample the ozonized test gas at nearly the same rate as in an actual flight. By relating the ozone signals to the readings of the other channels, the sonde sensitivity can be calibrated. The overall relationship is

$$S = KQ\frac{d\rho}{dt}$$

where S = ozone signal

K = calibration constant

Q = ozone mixing ratio

ρ = air density in ballast chamber

t = time

For a bench calibration, (at constant temperature) it can be shown that

$$S = K'Q\frac{dP}{dt},$$

where K' = a constant related to K

P = pressure in ballast chamber

Thus, by plotting S vs $\frac{dP}{dt}$, a straight line should be obtained, with a slope of K'Q. With Q known, K' and K are readily calculable.

III. PRE-FLIGHT ACTIVITIES

A. Preliminary

Parametrics, Inc. personnel arrived at WSMR approximately one week before the scheduled flight date, and concurrently with NASA personnel responsible for payload assembly, instrumentation, vehicle management, etc.

Assembly of the calibrator-simulator was initiated immediately. This apparatus, which includes several large pieces of glassware, was shipped to WSMR from Waltham, Massachusetts, and had sustained no appreciable damage. Assembly was completed within a day.

Two sondes, the flight unit and the backup unit, were brought to WSMR by NASA personnel. The flight unit was attached to the calibrator and "passivation" was begun. This consists of passing high ozone concentrations through the apparatus and the sonde in order to make all internal surfaces "inert" to ozone. This is especially important for the inlet tubing of the sonde, where ozone destruction can cause large errors. Approximately 48 hours of continuous passivation was needed to properly condition the sonde.

Electrical checkouts of the sondes were concurrently made. It was found that the 0-5 torr pressure transducer on the backup unit would not read below 3 torr. This malfunction is believed to have occurred during the environmental testing of the integrated payload at GSFC.

Troubles were also encountered with the chopper motor in the flight unit. This would occasionally fail to start when power was applied. At times, it would even stop running while powered. It appeared that these symptoms could be eliminated for a time by cleaning the contacts on the motor governor. This occurrence was surprising in that this motor was essentially brand new, having been operated for only a fraction of its rated life. (This trouble had been noted previously on the sondes, but was ascribed to the motors having been operated well past their rated lifetimes. The new motor was installed on the flight unit for just this reason).

Several calibration runs were performed on various luminescent discs, and a disc with satisfactory sensitivity was selected to be used for the flight.

B. Pre-Launch

Pre-launch activities were initiated at approximately t minus 4 hours. Up to that time, both the calibrator and sonde had been undergoing passivation with high concentrations of ozone. (The treatment was maintained at all times when the sonde was not in use, e. g. overnight, etc.). The system was evacuated, and then filled with dry air. The luminescent disc was inserted in the sonde, and the system re-evacuated. A calibration run was then performed. The system was then re-filled with dry nitrogen, and left standing for one hour. At this time, it was re-evacuated and another calibration performed. This process was repeated until about t minus 2 hours. At the conclusion of this calibration, after filling with nitrogen, the sonde was removed from the calibrator, and assembled into the remainder of the payload. Just before assembly, the motor governor contacts were cleaned. The entire payload was then positioned so that the sonde inlet port could be re-connected to the calibrator. At about t minus 1 hour the last calibration was performed. The sonde was then filled with nitrogen, removed from the calibrator, and the payload "buttoned up."

IV. FLIGHT RESULTS

A. Flight Sequence

The planned sequence of events after launch was as follows:

t = o - Nike ignition

t = 3.5 sec - Nike burnout

t = 17 sec - Cajun ignition

t = 21 sec - Cajun burnout

t ≈ 65 sec - Payload separates from Cajun, exposing ozone sonde inlet; ballast chamber evacuates.

t ≈ 75 sec - Parachute, T/M and ozone sonde separate from payload casing; parachute deploys.

As deduced from telemetry, all events were as scheduled except for the last one. For some reason (believed to be mechanical) the parachute did not deploy at high altitude; thus, the ozone sonde experienced a much more rapid descent rate then it had been designed for. This had several deleterious effects:

a) The values of $\frac{dP}{dt}$ were much higher than planned. This meant that the inlet flow rates were very high, and that there was undoubtedly ozone "breakthrough" (i. e. ozone was swept past the luminescent disc too rapidly for complete reaction to take place and the signal was not proportional to the ozone mass flow rate.

b) The very high (and rapidly changing) values of $\frac{dP}{dt}$ make it difficult to calculate these values from the T/M record.

c) The payload velocity very quickly became supersonic, leading to orientation-dependent pressure fluctuations for which no analysis had been made.

d) Because the payload was unstablized by a parachute, it appears to have tumbled. This may be s source of the intermittent signal drop-out which appears in the T/M record. Unfortunately, this drop-out (together with a "calibration" signal) makes it difficult to interpret the data in the region, just after apogee, where the sonde is not yet supersonic.

B. Ozone Data

Examination of the flight data in the region immediately after apogee does allow one to make some estimate of the ozone concentrations encountered by the sonde. Due to the difficulties mentioned above, this is an admittedly crude approximation; however it is felt that these numbers are probably accurate to within a factor of two:

Time After Indicated Apogee (sec)	Ozone Mixing Ratio ($\mu g/gm$)
7	1.00
12	0.99
17	0.81
22	1.32

Several points should be made concerning these data:

a) Due to the absence of reliable radar tracking information, no altitudes can be assigned to these points. Indeed, it is not clear whether or not the "indicated" apogee time (from the pressure transducer) was the true apogee time. It is possible, for example, that the ballast chamber was still evacuating after apogee had been reached.

b) The last azone point is derived from an interpolated value of $\frac{d\rho}{dt}$, as signal drop-out obscured the pressure trace from 19 to 26 seconds. When signal returned, the pressure was undergoing the periodic fluctuations mentioned above. Therefore, the "smooth" $\frac{d\rho}{dt}$ interpolation used in this region may not be valid.

c) These are probably lower-limit values, due to the possibility of ozone "break-through," mentioned above.

C. Instrument Performance

Although little useful ozone data was obtained, we do have a record of some other aspects of the sonde's performance:

a) The "calibration" signal, due to the incandescent lamp, appears to have changed appreciably in magnitude during the flight. Thus, pre-launch T/M indicates a signal of 3.4 volts, while the signal at t plus 66 seconds is only 2.6 volts. This might be due to the change in chopper motor speed mentioned below.

b) At launch, the chopping frequency increased abruptly from 0.88 cps to 1.33 cps. This frequency then appears to have slowly increased to 1.37 cps. The reason for this change is not known, although manipulation of the motor governor during cleaning of the contacts may have damaged it in some way. Another possible cause might be centrifugal forces due to the spin of the rocket, which may have changed the effective "neutral" position of the spring-loaded governor contacts.

c) Both pressure transducers appear to have operated normally. The point at which the sonde was exposed to ambient pressure is clearly indicated on the T/M record, and the indicated apogee time (minimum pressure) corresponds well with the predicted one. Unfortunately radar data is not available to check this.

d) The ballast volume temperature seems to be in error, indicating 65°F just before launch, after the instrument had been exposed (unpowered) on the launcher for nearly an hour to an ambient temperature of less than 50°F. Unfortunately this sensor was not calibrated before launch, although it had been calibrated at the time the sonde was constructed. Thermistors of this type are usually quite stable, and it is not known what caused the large apparent shift in calibration.

V. RECOMMENDATIONS

On the basis of the above results, the following recommendations are made:

a) The reason for the intermittent stoppage of the chopper motor should be investigated. Motors of other design should be contemplated for future sondes.

b) The abrupt change in motor speed at launch should be looked into. If possible, the behavior of the motor while the sonde is spinning should be studied. It should be relatively easy to determine whether the change in motor speed was responsible for the change in the "calibration" signal.

c) The thermistor on the recovered sonde, if still operational, should be recalibrated to see if this was responsible for the error in the temperature signal.

d) In future flights, steps should be taken to ensure reliable radar tracking; altitude vs. time data is an indispensable part of the ozone measurement.